AOARD REPORT

The 41st Japan Society of Applied Physics Spring Meeting Held Between 28-31 Mar 94 at Meiji University in Kawasaki, Japan

Mar 28-31, 94

S. J. Yakura
AOARD

The 41st Japan Society of Applied Physics Spring Meeting attracted a thousands of Japanese scientists and a few non-Japanese scientists coming mostly from Japanese universities, Japanese industrial research laboratories, and Japanese federally funded research centers. During a four day meeting, there were more than fifty simultaneous sessions in progress, covering most of the applied physics disciplines such as radiation and plasmas, measurements, optics, quantum electronics, optoelectronics, thin film physics, beam physics, applied materials, superconductivity, bioelectronics, semiconductors, crystal formations, and non-metallic formations. Presented here is an overview of papers presented in three topical sessions which covered the future and prospects of new light emitting materials, nanostructure control and single-electron electronics, and recent progress in silicon carbide and nitride related wide bandgap material research. Mr. S. Nakamura, Nichia Chemical Industries, Inc., presented the latest data on InGaN/AlGaN double heterostructure light emitting diodes, which showed a luminescence value of 1.2 candelas, corresponding to an increase in brightness by a factor of 100 as compared to the existing SiC diodes.

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

ASIAN OFFICE OF AEROSPACE RESEARCH AND DEVELOPMENT

TOKYO, JAPAN
UNIT 45002
APO AP 96337-0007
DSN: (315)229-3212
Comm: 81-3-5410-4409

AOARD-TR-94-10

Subject: Trip Report - The 41st Japan Society of Applied Physics Spring Meeting Held Between 28-31 Mar 94 at Meiji University in Kawasaki, Japan

Abstract

The 41st Japan Society of Applied Physics Spring Meeting attracted a thousands of Japanese scientists and a few non-Japanese scientists coming mostly from Japanese universities, Japanese industrial research laboratories, and Japanese federally funded research centers. During a four day meeting, there were more than fifty simultaneous sessions in progress, covering most of the applied physics disciplines such as radiation and plasmas, measurements, optics, quantum electronics, optoelectronics, thin film physics, beam physics, applied materials, superconductivity, bioelectronics, semiconductors, crystal formations, and non-metallic formations. Presented here is an overview of papers presented in three topical sessions which covered the future and prospects of new light emitting materials, nanostructure control and single-electron electronics, and recent progress in silicon carbide and nitride related wide bandgap material research. Mr. S. Nakamura, Nichia Chemical Industries, Inc., presented the latest data on InGaN/AlGaN double heterostructure light emitting diodes, which showed a luminescence value of 1.2 candelas, corresponding to an increase in brightness by a factor of 100 as compared to the existing SiC diodes.

I. Introduction

The Japan Society of Applied Physics (JSAP) Spring Meeting is one of the major technical meetings held in Japan twice a year to bring together scientists at one place and discuss progress in applied physics. It is sponsored by JSAP, which, I would say, is akin to the American Physical Society (APS). I, being a regular member of APS, did not have to pay the non-member registration fee for the 41st JSAP Spring Meeting since members of APS, the European Physical Society, and the Institute of Physics were given the same consideration as regular JSAP members. Following the tradition of holding the JSAP Meeting always on the ground of an university campus, this year's meeting was no exception and was held on the Kanagawa campus of Meiji University in Kanagawa Prefecture between 28-31 March 94. The campus is located less than a 30 minute train ride from both Tokyo and Yokohama stations. Structured very similar to APS meetings in the U.S., the number of papers, presented in this four-day long Spring Meeting, was up in a thousands. The meeting used the multiple session format. There were more than fifty simultaneous sessions held at one time to handle a large number of papers. The first three days were scheduled in full, both in the morning and afternoon. On the fourth day, the number of sessions was reduced to about a half of what it was in other three days. All the fourth day papers were in areas where Japanese have very active research programs. Areas included semiconductor lasers, thin film physics, optoelectronics and optical devices, III-V epitaxial growth, plasma electronics, electronic devices, semiconductor surface properties, manufacturing processes, and superconductors. All the accepted papers in regular sessions were presented orally and each presenter was given 10 minutes for presentation and five minutes for questions and answers. In addition to regular sessions, there were 25 special topical sessions, reviewing the current research activity by inviting well-known scientific experts to discuss recent accomplishments and future

directions within specific topical fields. Most of the papers in special topical sessions were invited papers and they were given 20 to 30 minutes for each presentation.

In the Meeting, there was good mixture of researchers from Japanese academia, industrial research laboratories, and federally funded research centers. In comparison with APS Meetings, the JSAP Spring Meeting had significantly higher percentage of papers presented by researchers working in industry. Those were in general good quality papers. It provided a good indicator for telling the amount of scientific research being carried out at Japanese industrial research laboratories. It has been the case for many years that Japanese companies have spent time and efforts to do their own scientific research for the purpose of improving their own product lines. Nowadays, their research activity has extended to include basic science in order to cultivate new technology. Without any questions in people's minds, the level of Japanese industrial research has reached a pinnacle of scientific achievement in a few selective technical fields, such as electronics and manufacturing, in last few years.

I attended three special topical sessions where Japanese scientists have done an extensive amount of research in last few years. The first session dealt with the future and prospects of new light emitting materials. The second session discussed Japanese research efforts in the area of nanostructure control and single-electron electronics. The third session covered recent progress in silicon carbide and nitride related wide bandgap material research. In this report I focused my efforts into reporting the merits of recent progress made in these research areas.

An highlighted event came in the third session when I had an opportunity to hear a talk-of-the-town paper by Mr. Shuji Nakamura of Nichia Chemical Industries, Inc, who reported the recent breakthrough in blue light emitting diode research. He presented the results of using Indium Gallium Nitride/Aluminum Gallium Nitride double-heterostructure for coming up with a very bright light emitting diode at around 450 nm (blue). He reported a brightness value of 100 times that of the existing blue light emitting diode based on silicon carbide (SiC) technology. Mr. Nakamura commented that it is a matter of time before somebody would come up with a blue GaN diode laser, if it is not by him. As the result of his accomplishment, I may like to say that blue laser research in III-V compounds has taken a big step forward. It also represent a very interesting foretell in the future of zinc selenide (ZnSe) research. Once the blue laser is developed based on GaN technology, it would be interesting to see the change in ZnSe research activity. It allows industrial firms to have an option of selecting one more technology, namely GaN technology, among many other technologies, such as ZnSe, second harmonic generation using red lasers, available to build compact blue laser devices.

II. Special Topical Sessions

The following discusses some important aspects of three special topical session which I have attended.

IIa. Topical Session #1 - The Future and Prospects of New Light Emitting Materials and Phenomena (28 Mar 94)

In this special topical session, there were eight papers presented altogether. Unlike regular session papers, all the papers in this session were given 30 minutes for presentation.

Prof. Hiroshi Kukimoto, Tokyo Institute of Technology, presented the first paper. He basically gave an overview of the subject matter to the audience. It was a very short presentation and lasted for only around 10 minutes. Prof. Kukimoto discussed a few basic approaches that scientists have been using to look for new light emitting materials. Based on the current need of light emitting materials for ever expanding optoelectronics and photonic fields, he said that it is time to consider more of the applications. He pointed out that it is important for the future light emitting materials to have the following properties: 1) good optical compatibility with the existing silicon-based devices; 2) ability to operate under high temperature conditions; 3) exhibiting no harmful impacts to the environment; and 4) has specific applications in biochemistry, bioengineering, space technology.

The second paper entitled "Disordered Superlattices and New Optical Properties" was presented by Prof. Akio Sasaki, Department of Electrical Engineering, Kyoto University. He reported the current status of research in artificially grown new optical materials which exhibit the disordered superlattice behavior. On the contrary to the usually known ordered superlattice structure of $(AlAs)_m/(GaAs)_n$ m, n = v, the artificially grown disordered superlattice structure can be shown to have m and n values of v/2, v, 3v/2. As became clear from the recent experimental results of AlGaAs types, which exhibited at least 500 times luminescence than that of the ordered superlattice structure at 77 degrees Kelvin, the disordered superlattice structure can indeed increase the luminescence significantly. However, there is one undesirable effect observed in the experiment. The experiment has shown that the emission spectrum has been shifted slightly to the longer wavelength. Prof. Sakaki suspects that the strain caused by disordered superlattice structure in crystal is causing an increase in luminescence.

In the third paper, Dr. Koh Era, the National Institute for Research in Inorganic Materials, Science and Technology Agency of Japan, discussed cubic boron nitride (cBN) and diamond research in Japan. Based on theoretical calculations and experimental data, it is estimated that cBN bandgap energy is around 6.3ev, which is larger than the diamond bandgap energy of 5.49 ev (@100 K). The cBN crystal has been grown using the high pressure flux technique for all the experiments performed thus far. Only recently the chemical vapor deposition technique has been used successfully to grow cBN crystals. Yet, There is no experiments carried out to investigate properties of cBN using the CVD grown cBN.

One important feature of cBN, which differs from diamond, is that cBN can be made into p and n type materials. It gives cBN an honor of being identified as the widest bandgap semiconductor material. At a bandgap energy of 6.3 ev, one expects a wavelength close to 200 nm, which is the shortest wavelength among any semiconductors. Because of the lack of research activity in cBN and difficulty in performing cBN experiments, as of today, no concrete evidence is obtained from any experiments which reveal the emission spectrum at close to 200 nm. It seems that more time and money is needed to really understand properties of cBN. With the renewed interest in high temperature electronics, cBN research may pick up its activity in the near future. There are some desirable cBN properties that we cannot overlook for very specific applications, especially in very high temperature operation.

In the fourth paper, Prof. Yoshihiko Kanemitsu, Institute of Physics, the University of Tsukuba, discussed his contribution to a study of quantum size effects of nanometer-size

silicon crystallites. The interest on this subject is very recent which started in 1990 with a report of strong photo-emission from porus-silicons. The current level of research is very basic in nature. There are many basic questions needed to be answered. As part of carrying out basic research in this new area, it became apparent that the surface effect becomes more and more important in analyzing the nanometer size structure. Currently, Prof. Kanemitsu is trying to understand fundamental mechanisms associated with photo-emission effects in nanometer size silicon crystalline due to the quantum size effect. His recent accomplishments can be seen in three journal papers that appeared in 1993 issues of the Journal of Phy. Rev. B.

The fifth and sixth papers described the change in optical properties of polymers which are doped with different atoms or molecules. These papers were presented by Dr. H. Tachibana, the National Institute of Materials and Chemical Research, and Prof. K. Yoshino, Osaka University. The fifth paper discussed the effect of doping with silicon and germanium atoms, whereas the sixth paper discussed the effect of doping with fullerene. There are extensive research efforts being carried out at the National Institute of Materials and Chemical Research and Osaka University.

The seventh and eight papers looked at the future and prospects of new light emitting materials from two extremely different view points. The seventh paper, presented by Dr. H. Yokoyama, NEC optoelectronics laboratory, was geared toward more in the line of utilizing basic and proven ideas to design new optical devices. By combining two or more ideas, it is possible that an optical device exhibits the unexpected results which can be used for different applications than originally intended. Dr.Yokoyama based his talk on three questions, specifically on the following: "Is there new physics?", "can we make devices?", and what can we use them for?". On the contrary, the eighth paper, presented by Prof. Testuo Ogawa, Osaka City University, was very theoretical in nature. He discussed the merit of dimensionality analysis in studying the optical response of materials. I found these papers a bit out of scope from the topic discussed in this session, although they had some merits.

IIb. Topical Session #2 - Nanostructure Control and Single-Electron Electronics (29 Mar 94)

In this topical session, there were nine invited papers. Of nine one came from the US. It was presented by Prof. D. Averin, Department of Physics, SUNY. Four came from Japanese industrial research laboratories consisted of NTT Optoelectronics Laboratory (Dr. T. Tamamura), Toshiba Advanced Research Laboratory (Dr. S. Iwabuchi), NEC fundamental Research Laboratory (Dr. Y. Nakamura), and Hitachi Central Research Laboratory (Dr. K. Yano). Three came from Japanese academia, consisted of Toyo University (Prof. T. Sugano), Tokyo institute of Technology (Prof. M. Asada), and the University of Tokyo (Prof. S. Katsumoto). Just one came from a Japanese federally funded research center, RIKEN (Dr. H. Isshiki).

Outlines below are titles of invited papers in the order which they were presented.

- "Introduction to Nanostrucure Control and Single-Electron Electronics" by Prof. Sugano.
- "Single Electron Charging Effects in Semiconductor Hererostructures" by Prof. Averin.
- "Nano-Fabrication Using Electron Beam Lithography" by Dr. Tamamura.
- "Formation of Semiconductor Nanostructures By Selected Growth" by Dr. Issaki.

- "Coulomb Blockade in Ultra-Small Double Junction With External Circuits" by Dr. Iwabuchi.
- "Quantum-Effect Devices Using Metal/Insulator Heterostructure" by Prof. Asada.
- "Coulomb Blockade in Arrays of Small Metallic Particles" by Prof. Katsumoto.
- "Charge Injection Into a Single-Electron Box" by Dr. Nakamura.
- "Room Temperature Operation of a Single-Electron Silicon Memory" by Dr. Yano.

The session provided a good overview of the status of the current research activity in nanostructure and quantum effects, specifically related to the single-electron charging effects. The research in this area is very active not just in academia but in industrial sector because of the potential for making ultra-high density memory chips. It is just for that reason the four major Japanese electronics companies, as mentioned above, are involved heavily in this research area. The research activity has really picked up the pace in last few years when fabrication technology has improved to a point where it is possible to fabricate metallic and semiconductor structures down to the size of a few nanometers.

An idea behind making an ultra-high density memory chip is very simple. It is based on capturing or uncapturing of a single electron inside a nanometer size metal or semiconductor structure.

The first two papers presented the background of single-electron electronics in nanometer size structures. The second paper, presented by Prof. Averin, discussed theory of the single-electron tunneling in semiconductor heterostructures and its application in coming up with new electronics devices, such as very sensitive electrometers and ultra-high density memory chips. Prof. Averin expressed his view on the results of extending single-electron experiments in double-barrier structures into mutli-barrier structures. Thus far, single-electron tunneling is studied only experimentally in double-barrier structures. He expects that in multi-barrier structures one should observe the existence of Block and single-electron oscillations as well as single-electron quantization of the high-field domains due to the interplay between miniband transport and single-electron charge effects.

One paper that had most significance was the last paper by Dr. K. Yano. He presented the results of the first room-temperature operation of a single-electron silicon memory. It presented the real breakthrough in this field. It has been thought that single-electron silicon devices need to be operated at very low temperatures around a few degrees Kelvin. To achieve the room-temperature operation, Dr.Yano and his associates had to work on the following technologies: 1) fabrication technology to grow a 100 nm width and 4 nm thick plate consisting of 10 nm or smaller size silicon crystals structures. It is used as a memory node; and 2) transistor technology to create what Hitachi called the "single transistor type memory structure." It is structured with three arms extending outward from the center of the device where they are used for source, gate, and drain. The center of the device is where the memory node is placed.

IIc. Topical Session #3 - Recent Progress in Silicon Carbide and Nitride Related Wide Bandgap Material Research (30 Mar 94)

There were eleven papers presented in this topical session. The first speaker was Prof. Hiroyuki Matsunami, Kyoto University, who gave an introductory talk based on progress in silicon carbide crystal growth research, which is his primary research area. Other speakers were Dr. J. Takahashi, Nippon Steel Corporation Electronics Research

Laboratory (Growth of Large SiC Single Crystals); Dr. T. Kimoto, Kyoto University (Crystal Growth of High-Quality SiC by Step-Controlled Epitaxy); Dr. S. Nakashima, Osaka University (Characterization of the Electron Properties of SiC by Raman Scattering and Infrared Reflection Techniques); Dr. Suzuki, Sharp Central Research Laboratory (Doping Characterization of CVD Grown SiC Epitaxial Films); Dr. H. Fuma, Toyota Central Research and Development Laboratories (SiC Metal-Oxide Semiconductor Characteristics); Dr. K. Ueno, Fuji Electric Research and Development, Ltd. (Applications of the SiC Semiconductor to Electron Devices); Dr. Y. Matsushita, Sanyo Electric Microelectronics Research Center (Recent Progress and Future Forecast for the Improvement of SiC Blue LED's Efficiency); Prof. H. Amano, Meijo University (Short Wavelength Light Emitting Devices Based on Column-III Nitride Semiconductors); Mr. S. Nakamura, Nichia Chemical Industries, Ltd. (InGaN/AlGaN Double Heterostructure High Brightness Blue Light Emitting Diode), and Dr. S. Yoshida, MITI's Electrotechnical Laboratory (Prospect of Research on SiC and related Wide Bandgap Semiconductors).

As seen by titles of papers presented in this session, ones could see that most of the talks were on SiC research. It showed the amount of SiC research being carried out at many industrial research laboratories. It is only in the last few years the GaN research activity has really picked up the pace. Although there were just two GaN papers presented here, one of the them, which was presented by Mr. Nakamura of Nichia Chemical Industries, Inc., had reported a factor of 100 improvement in luminescence of blue light emitting diode (LED) using an InGaN/AlGaN double-heterostructure over the existing SiC diodes. Specifications of his GaN LED included an emitting wavelength of 450 nanometers (blue), at an output power of 1500 microwatts at 20 milliamperes and 3.6 volts applied voltage, and an luminance value of 1200 millicandelas. He has grown GaN layers on the sapphire (Al_2O_3) substrate. The structure of the GaN LED used the layers of n-type GaN, n-type AlGaN, InGaN, p-type AlGaN and P-type GaN stacked up on top of the sapphire substrate. Each layer was fabricated by means of the metal organic chemical vapor deposition method. At first, polycrystalline GaN was grown as a buffer layer on the sapphire substrate at the substrate temperature of 550 degrees Celsius. The n-type GaN second layer was grown at 1000 degrees Celsius. On top of it, n-type AlGaN was grown followed by the Zn doped InGaN used for light emitting layer. The p-type layers, which includes AlGaN and GaN were then fabricated by using Mg as dopant and by heat treating the formed films at 700 degrees Celsius in an N_2 gas reactor container. Finally an electrode is placed at the very top of the double heterostructure device. He commented that he doped InGaN to up shifted the wavelength to 450nm. Without doping he measured the peak wavelength to be at 400nm. He stressed that all the data were taken at room temperature.

On the contrary to its recent accomplishment in GaN, SiC crystal growth research has been struggling to remove undesirable ten micron size, long pipe like features that appeared during the crystal growth. Because SiC has the potential to be used as the hybrid device with silicon devices, one would hope that there is a technical breakthrough in the near future to make aware of the usefulness of the SiC devices. It seems that there is no light at the end of the tunnel yet for SiC technology.

III. Concluding Remark

At the 41st Japanese Applied Physics Spring Meeting, I saw a number of interesting papers. It is a good place to find out the general trend of Japanese research activity. It was especially useful to attend special topical sessions, which provided good overviews on the current research areas of interest.